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Field Measurement Of Existing Noise Levels

MATERIALS BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
Hugh L. Carey, Governor / Raymond T. Schuler, Commissioner

Revised Sept. 1976

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NOISE MEASUREMENT UNIT

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PREFACE

This revised manual reflects the experience of two years of operation for the Noise Measurement Unit. A major change is the requirement that all measurements consist of at least 100, rather than 50, 10-second readings. About two-thirds of the past measurements already needed at least 100 samples. This change will not require any past measurements to be redone; they are still valid. It will, however, give stronger assurance that the sample period is truly representative of the entire hour being described.

A second major change is in the traffic classification rules. Past counting of 2-axle, 6-tire vehicles exclusively as trucks has led to high traffic noise level calculation by the prediction program. Study has shown it much better, if not yet perfect, to classify these vehicles as either automobiles or trucks depending on their apparent relative loudness.

More information has been added on site selection, again reflecting our experience. The text of PPM 90-2 has been replaced with excerpts from its successor, FHPM 7-7-3.

Principal author of the original manual was Peter A. Chiefari, P.E., Assistant Civil Engineer (Materials) in the Noise Measurement Unit. His dedicated work in pulling everything together made the manual a reality. These revisions were mainly prepared by William Bowlby, also Assistant Civil Engineer (Materials) in the Noise Measurement Unit.

The hard work and essential contributions of Orlando E. Picozzi, who, among everything else, revised the data forms and instruction, and Richard W. Carlson and Thomas F. Nelson, formerly of the Noise Measurement Unit, were integral to the original manual's preparation.

The manual's development was immeasurably aided by the review and comment of many people, including Wm. P. Hofmann, James J. Murphy, Robert J. Perry, William McColl, Louis F. Cohn, William R. Webster, David E. Suuronen and all Regional Noise Liaison Engineers.

A. D. Emerich of the Engineering Research and Development Bureau was responsible for the final review and preparation of the original manuscript. Numerous early drafts and associated notes and memorandums were typed by Arlene A. Stipano, Jo Simmons, Debie A. Lezatte, and Angel A. Serio.

Special thanks go to Cecilia M. Leonard for typing much of the revised edition.

CONTENTS

INTRODUCTION

In the late 1960's, concern in many circles turned increasingly to our environment. Various laws were passed, designed to achieve minimum quality standards for air, water, and land, and to abate the waste of our natural resources. A fourth pollutant, less frequently recognized, is noise. The collection of sounds created by our advanced industrial society has reached a level that can no longer be ignored. One has merely to stand on a crowded city street corner during rush hour to realize the importance of controlling noise.

A major contributor to the noise in our daily lives is the ever-increasing stream of automobiles and trucks riding our nation's highways. Thus, in 1970, legislation was passed that resulted in noise standards designed to control the increasing noise levels associated with highway traffic. These standards were set forth by the Federal Highway Administration (FHWA) in its Policy and Procedure Memorandum 90-2, Revised in May 1976 as FHPM 7-7-3 (Appendix G).

To implement these standards, and in doing so, to help maintain and improve the quality of our environment, the New York State Department of Transportation has created a program to measure highway-related noise. One outgrowth of this program is the Noise Measurement Unit of the Materials Bureau in Albany, which has overall responsibility for noise measurement for the entire Department. Also, each region has designated a Regional Noise Liaison Engineer (RNLE) whose responsibility is to supervise the regional noise measurement program.

The ten regional noise measurement units are charged with measurement of noise as it relates to the Department's environmental impact assessment program. The Main Office Noise Measurement Unit's function is to support the regional units with training, equipment allocation, computer record maintenance, and general coordination of a quality noise measurement system. A third group, the Environmental Analysis Section, is also located in the Main Office. One of its functions is to provide support for the regional noise analysis effort.

As a Noise Measurement Technician (NMT), you are the field arm of this organization. It is you, the NMT, who will be measuring noise in the field. This manual is written specifically for you. It's designed to be both a field guide and a reference explaining the basic science of sound, noise, and noise measurement. It has three sections:

I. Sound and Noise Fundamentals.

II. Measurement of Existing Noise.

III. Noise Field Test Methods.

Section I gives the basic science of sound and noise -- what they are and how they are defined for measurement purposes.

Section II deals with the specifics of noise measurement, with emphasis on highway-related noise.

Section III gives field test methods for noise measurement, explaining in detail the equipment and procedures and the necessary paperwork.

One further point -- as a Certified NMT, you have a particularly high level of responsibility. Noise must be measured by strictly adhering to field test procedures. Mistakes in obtaining noise data are not always readily detectable. If the data appear incorrect, the only alternative is to go out and re-measure for verification. Unfortunately, many times this is not possible.

Your measurements will be one factor in transportation decisions. Once you are a Certified NMT, the Department will have to rely on your measurements, and possibly even defend them in court.

Everyone in the state will benefit if we reduce noise levels. Noise is here to stay, but with your help, we can design measures to control it. Doing your job to the best of your ability will help improve our environment.

I. SOUND AND NOISE FUNDAMENTALS

A. Sound Waves

Since we are concerned with noise it seems logical to start with the question: what is noise? The best definition is the most simple. Noise is unwanted sound. Fine. But what is sound? We've taken it for granted since childhood. We hear "sounds." Technically, sound is defined as a wave disturbance moving through an elastic medium at a speed characteristic of that medium. That really doesn't help much. Let's try it this way. On a nice day you're sitting by a lake. The surface of the water is relatively flat. You're fishing for bass. They aren't biting, so you pick up a rock and toss it into the lake. When the rock hits the water it causes waves in the form of rings that move outward for the point where the rock enters the water. The rock has disturbed the water from its equilibrium (flat) level, and the waves move outward and eventually die out.

Now, as we said, sound is also a wave. The difference between the water wave and a sound wave is that sound is a disturbance in the air. More correctly, the sensation of "sound" is caused by the ear detecting changes from atmospheric pressure. When a bass drum is struck, the drumhead begins vibrating (rapidly moving up and down), causing waves in the air, just as the rock caused waves in the water. These waves are detected by our ears as very tiny changes from the equilibrium (or atmospheric) pressure. These pressure changes are converted through the internal workings of the ears into a message that is sent to the brain. The result is that we "hear" the sound of the bass drum.

Water waves, sound waves, and in fact, all waves can be described by two characteristics:

1. AMPLITUDE.

2. FREQUENCY.

In the case of the water waves caused by the rock, the amplitude of the wave is the height of the water above or below the undisturbed (flat) water surface. Another way of saying this would be that the amplitude of the wave is equal to the "magnitude" (height) of the "disturbance" (change in water level) above or below the "reference" or "equilibrium" level (undisturbed flat water surface).

Now suppose a pole were sticking out of the water near where the rock hits. If we counted the number of waves passing the pole for, say, 5 seconds and divided that number by the 5-second time, we would know the frequency of the wave. In other words, the frequency of the wave is equal to the number of

waves occurring in a unit of time. One complete wave is known as one cycle. In the case of the bass drum, when the drumhead is struck it is pushed down. The drumhead then springs back up, completing one cycle. The number of times it springs up and down (vibrates) per unit of time is the frequency of the sound wave produced.

For the case of a water wave, Figure 1 shows the relationship between frequency and amplitude. Case 1 shows an amplitude of 1 in. above and below the equilibrium water level and a frequency of 1 cycle (i.e., one complete wave) in 10 sec, or 0.10 cycles per second. The term "cycles per second" has been given the special name hertz, abbreviated Hz. Therefore, 1 cycle per second equals 1 Hz. In Case 2, the wave has an amplitude of ± 1 in. and a frequency half that of Case 1, or 0.05 Hz. In Case 3, the frequency is the same as in Case 2, but the amplitude is now 2 in., or twice that in the other two cases.

To summarize briefly, noise is unwanted sound. Sound is a wave disturbance in the air similar to a water wave. They are similar because all waves can be described by two characteristics -- amplitude and frequency. For a sound wave, the amplitude is the magnitude of the variation from atmospheric pressure, and the frequency is the number of disturbances per second. Frequency is expressed in hertz, abbreviated Hz.

One further comment -- the sound we will measure in the field is composed of not only one sound wave, but is a summation of a number of separate sound waves, each with a different frequency and amplitude. These different waves add up to produce the overall sound wave. An example of this is an orchestra. Each instrument produces a sound wave, and they all add up to give the orchestra's overall sound.

B. Sound Pressure Level

The human ear is sensitive to a large range of pressure disturbances. The change from atmospheric pressure caused by a cricket chirping at night is very tiny compared to the change from atmospheric pressure caused by a jet engine at an airport, yet the human ear can detect either.

Because of this large range of pressure disturbances that the ear can detect, it would not be practical to compare sound waves on the basis of pressure disturbances. To use the water wave example, this would be like comparing the ripples in a puddle to a tidal wave. So, to compare sound wave amplitudes, we use sound pressure level (abbreviated SPL), which is defined in such a way that the large pressure ranges possible are compressed into a smaller scale. (How this is done is explained in Appendix F.) The units of sound pressure level are called decibels.

The sound pressure level in decibels (abbreviated dB) then allows us to compare sound wave amplitude without the problems that we would have if we tried to compare them directly in terms of pressure disturbances. Figure 2 gives SPLs, in decibels, for various common indoor and outdoor sounds. The SPL of a person talking at a distance of 3 ft is about 65 dB. A jet airplane at 1,000 ft causes a much larger disturbance; hence, the SPL is 105 dB.

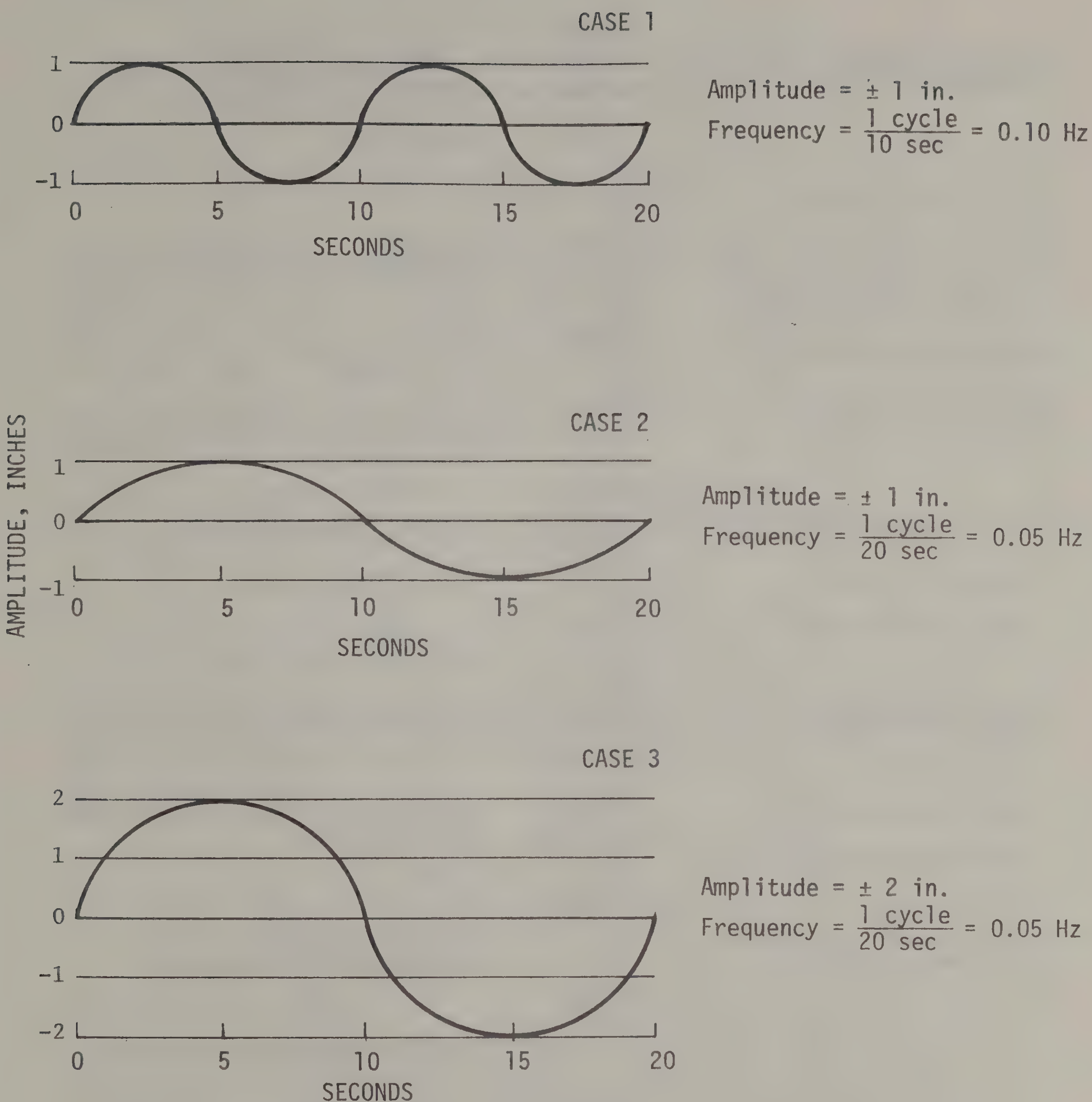


Figure 1. Frequency and amplitude of water waves.

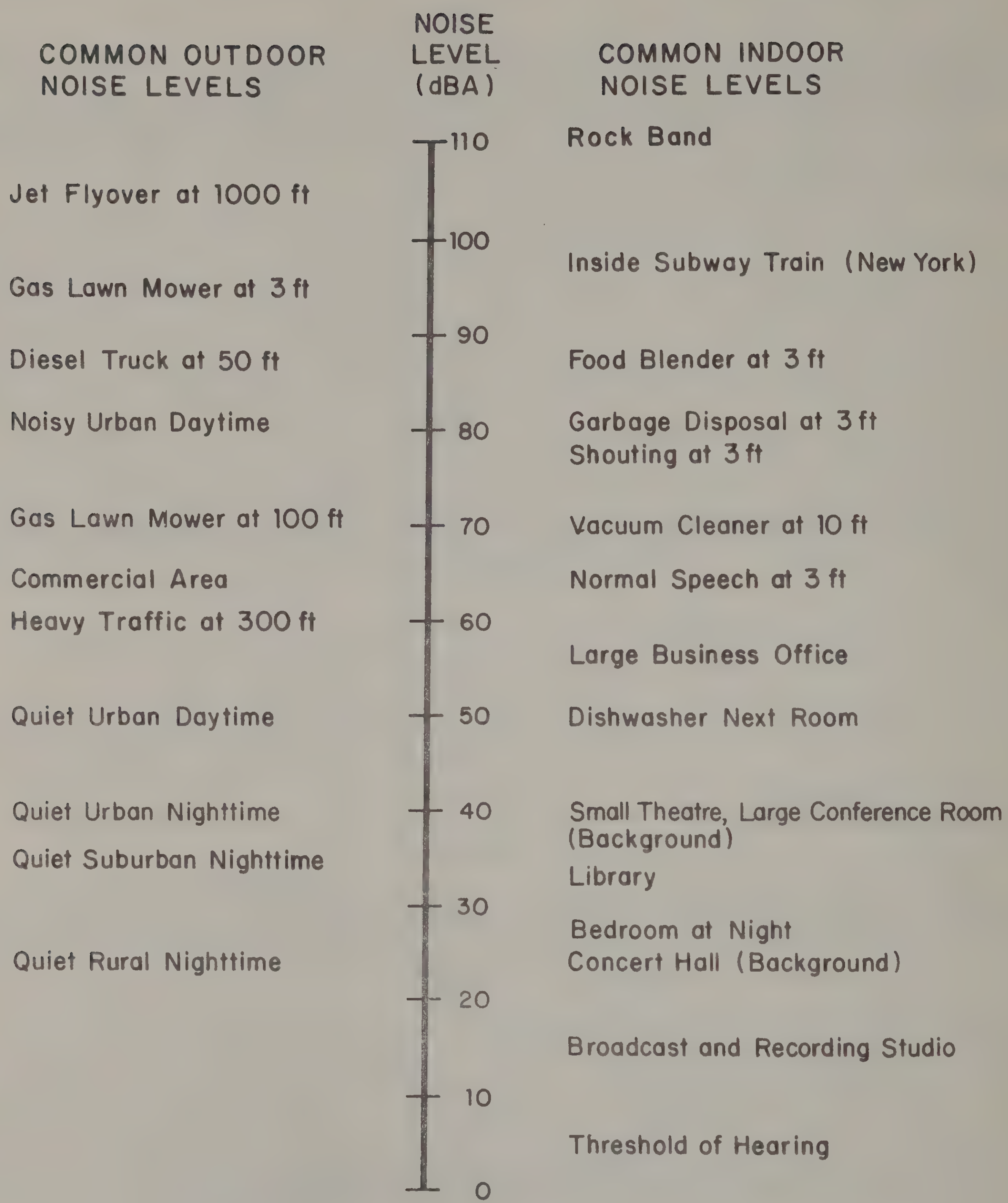


Figure 2. Common indoor and outdoor noise levels.

To summarize again, noise is unwanted sound. Sound is a pressure disturbance and Sound Pressure Level or SPL is related to the magnitude of this disturbance. The units of SPL are decibels, abbreviated dB.

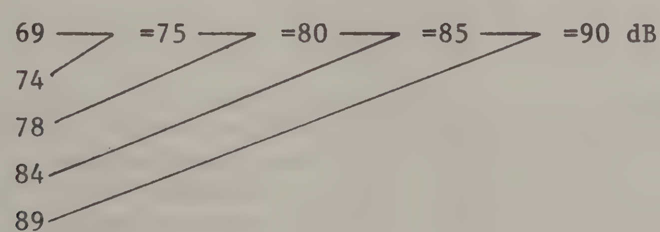
C. Addition of Decibels

There is one important difference between decibels and, for example, feet or pounds. If two boards are each 10 ft long, then their total length is 20 ft. However, if two trucks each create a SPL of 70 dB, then their total SPL is not 140 dB but only 73 dB. (This is because of the mathematical definition of SPL in dB; this definition and a proof of the above are given in Appendix F.)

Using the following table and method, any number of sound pressure levels may be added with an accuracy of ± 1 dB.

When two decibel values differ by	Add the following amount to the higher value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 or more dB	0 dB

To illustrate, we will add the following levels: 69, 89, 84, 74, and 78 dB. The first thing to do is rank the sound pressure levels in ascending order. They are then added pair-wise, according to the preceding table, beginning with the lowest pair:



69 dB + 74 dB = 75 dB
75 dB + 78 dB = 80 dB
80 dB + 84 dB = 85 dB
85 dB + 89 dB = 90 dB

Notice also that for differences of 10 dB or more, the number of decibels added to the higher value is zero. This means that if one sound is stronger than another by 10 dB or more, the lower sound is effectively "drowned out" by the higher one. This effect is called "masking."

D. The A-Scale Weighting Network

Just as the human ear is sensitive to a large range of pressures, it is also sensitive to a large range of frequencies. For most people, the normal fre-

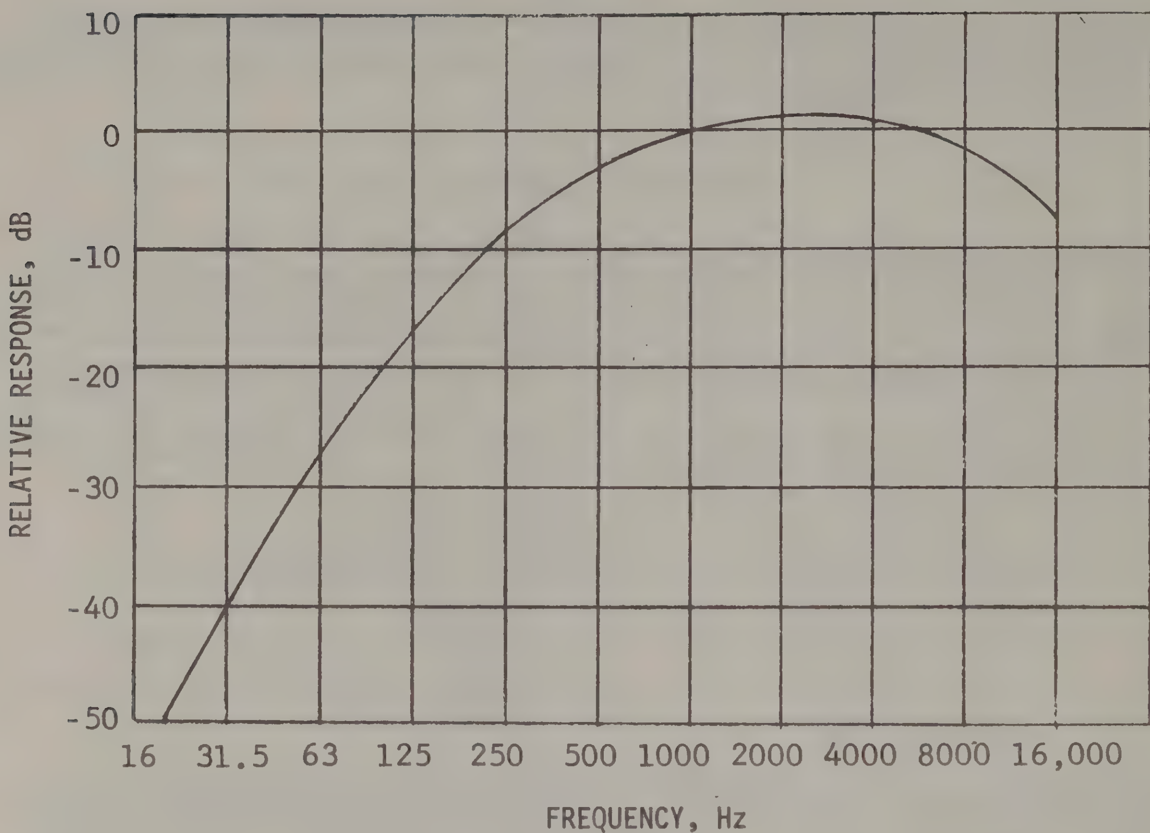


Figure 3. Electrical frequency response specified for the A-scale filter of sound level meters (ANSI SI.4-1971).

quency range of hearing is from 20 to 10,000 Hz, and in some cases as high as 20,000 Hz. However, the human ear does not "hear" each frequency equally. It is less sensitive to low-frequency sound than to high-frequency. Since we want to measure noise in a way that compares closely to the human ear's sensitivity, the A-scale weighting network has been devised.

The A-scale network (within the measuring equipment) electronically adjusts some of the higher and lower frequencies when the SPL is measured. The sound-measuring device then responds in a manner very close to the response of the average human ear, givin us a good idea of how the average person would perceive that sound.

The A-scale changes the SPL as shown in Figure 3. From this graph it can be seen that at 100 Hz, the SPL is diminished by 20 dB. At 1,000 Hz the SPL is not changed at all, while at 2,000 Hz, the SPL is increased by 1 dB.

From this point on, we will no longer use the term SPL in dB, but rather the term "sound level." By this we will mean an SPL measured in dB with an A-weighting network. Thus, sound level will mean the result of an A-weighted measurement. Any sound level will then be an approximation to the response of a human ear. Also, for our sound levels from here on, the results will be

reported as dBA, not dB. Thus, if the sound level of a passing car were measured, the results would be reported as 67 dBA, not 67 dB.

E. Sound Reduction and Reflection

When the rock in the water-wave example hit the water, waves were created and radiated outward at a certain speed. As they moved farther and farther out, they became smaller (attenuated) until they finally disappeared.

The same thing happens with a sound wave -- the farther from the sound source, the smaller the disturbance. Consequently, the sound level decreases with distance from the source. For example, the farther you are from a truck moving down the highway, the lower the sound level will be. If there is a high concrete wall between you and the highway, the sound level will be still lower, because some of the sound the truck generates will be reflected away by the wall. This can also work in reverse. If a building is close behind you, some of the sound waves may be reflected back to you, causing the sound level of the truck to be higher than it would be without the reflected sound. Rows of houses or possibly even a densely wooded area between you and the highway may also reduce the sound level.

The reason for mentioning these facts will become apparent later in this manual when we discuss the selection of measurement sites. For now, however, it is important to remember the following rules which apply to a site having an unobstructed view of the highway:

1. For a single car or truck proceeding down a highway, for every doubling of the distance from the road the sound level should drop approximately 6 dBA.

2. For a line of cars -- that is, a fairly uniform stream of traffic -- for every doubling of the distance from the road the sound level should drop approximately 3 dBA.

"Doubling the distance" means that if you are 50 ft away and get a sound level of 59 dBA, then at 100 ft you should get 53 dBA for a single car and 56 dBA for a stream of traffic.

This concludes our discussion of the fundamentals of sound and noise. It has been very basic. Appendix E of this manual gives references for further reading.

II. MEASUREMENT OF EXISTING NOISE

A. Traffic-Related Noise Sources and Existing Noise

1. Existing Noise

In Section I, we explained how the sound we measure is not simply one wave, but a combination of waves like an orchestra. Likewise, in the field, the activities usually occurring around a site produce a combination of sounds. This combination of sounds is commonly referred to as existing or ambient noise.

The existing noise level is obtained by measuring the sound level produced by those activities normally occurring in the site area. In the case of a site located close to a highway, a major portion of the existing noise will be from vehicles traveling down the road. If we are near a highway close to an airport, existing noise will also include noise of the aircraft. If we are in an isolated area, birds, crickets and rustling leaves may produce all of the existing noise. We will say more about the subject later. For now, it is sufficient to remember what existing noise is.

2. Automobiles, Trucks, and Other Vehicles

In most cases, we will be measuring existing noise whose major component is from highway traffic. Extensive measurements have shown that you can expect automobile sound levels to vary between 60 and 75 dBA and truck sound levels from 75 to 90 dBA or more at about 50 ft from the roadway. The large variations are due to such things as vehicle acceleration, speed, and condition; tire tread condition and type; and roadway surface roughness and grade.

Since there are relatively large variations between automobiles and trucks, we can see that it is very important to know how many trucks go by and how many automobiles; if we had only trucks going by, the existing noise level would generally be higher than if we had only cars.

Knowledge of the number of cars and trucks is necessary to help predict future sound levels, since it is reasonable to assume that altering an existing highway or putting a new highway in an area may increase traffic or change the relative number of automobiles and trucks, possible resulting in higher noise levels. For these reasons, traffic counts will be made during measurements.

Now, although this may sound odd, for our measurements what is a car and what is a truck? And how about motorcycles? Everyone has heard a

souped-up sports car. Some are very loud. Some motorcycles are also quite loud -- as loud or louder than some trucks. To solve this problem, we will observe the following rules in classifying vehicles:

1. There will be three general classes based on noise emission level. Separate counts for two of these classes - automobiles and trucks - will be kept.

2. Any four-tire, two-axle vehicle including sports cars, pick-up trucks, and small vans will be counted as an automobile.

3. Any three or more axle vehicle including commercial buses will be counted as a truck. (Note: FHPM 7-7-3 defines a truck as a vehicle over 10,000 lbs. We, however, use the above rule as a convenient method for counting and classifying trucks for noise measurement purposes.)

4. Any two-axle, six-tire vehicle or motorcycle will be counted as either a car or truck depending on how loud it is. Although this may seem a very doubtful way to classify them, a little field experience will show that it is quite easy to determine. If the vehicle is considered as loud as an automobile, it will be counted as an automobile and one vehicle will be added to the automobile count. Similarly, if it is as loud as a truck it will be counted as a truck.

Now, let's look at how we should go about taking measurements.

B. Basic Principles of Existing Noise Measurement

Measurement of noise for evaluation and possible control requires 1) a device that measures sound level, 2) a plan of where and when to measure, 3) a measurement method for collecting the noise data, and 4) a method to record and reduce the data. Stated more simply:

1. Equipment -- what do we use to measure?

2. Site and time selection -- where and when do we measure?

3. Method -- how do we measure?

4. Data Recording and Reduction -- what do we do with the measurements?

1. Measurement Equipment: The Sound Level Meter

Noise can be measured in many ways, using many types, sizes, and kinds of equipment. The most basic piece of equipment for measuring sound level is the sound level meter. All sound level meters perform the same basic function -- they measure the sound level. Components and controls are

similar on most models. Components usually consist of a microphone, an amplifier, an A-weighting network, and a meter calibrated in decibels. The controls include an on-off switch, a meter response setting (fast-slow), a battery check switch, a weighting network selector, and a range switch. In addition, there is usually a calibration adjustment. (The functions of each of these controls for our equipment will be explained in Section III.)

Just as with any piece of equipment, the sound level meter has certain operating limitations. For instance, the microphone attached to the meter will not work if the humidity is too high or if it becomes dirty. Temperature extremes can be detrimental to the meter's electronics, especially prolonged exposure to direct sunlight. High winds may also result in erroneous measurements.

2. Selection of Measurement Sites and Times

Once the equipment to perform the measurements is chosen, the next step is to decide where and when to measure. Deciding "where" is actually a two-stage process. The general location of a measurement site is normally indicated on a map of a proposed project. This site is selected by careful study of the map, and/or by preliminary field investigation. Sites are generally chosen to measure existing noise levels near noise-sensitive activities such as schools, hospitals, churches and houses. They are also chosen to provide a general picture of the noise level over an entire area. The exact site location in the field is selected by the measurement team.

The most important fact to remember in selecting a site is that measurements need to be representative of that area and its typical activity. So, in general, the equipment should not be set up close to a building, or a sign, or a parked car, or any object that might distort the sound field. (However, it should also be understood that sometimes measurements may be needed from an area full of reflective surfaces (e.g. trees in a wooded area). These sites should be measured as specified by the RNLE, noting any special circumstances that are present.)

It is also important to know the location of the site. This should be done by drawing a small diagram showing approximate footage from a distinguishing landmark or from the roadway if the site is near one. The distance from the landmark or roadway should be paced off, or tape-measured if so desired by the RNLE. The diagram and description should be sufficiently clear and complete to allow another measurement team to locate and set up at the exact spot.

The "when" to measure may be very dependent on the location. We may want to measure a particular site at a particular time. For instance, we may want to measure the effect of a highway on a site located close to a school. At the time the measurement team is present, school may just be letting out. It may be necessary to come back when classes are in session. In any event, the fact that school was just getting out should be noted along with the time the measurements were taken.

Also, there may be a temporary noise source near the site that is not typical of the usual activity near it. Examples would be a tree-cutting crew, water line repair crew, or a police or fire emergency. Measuring the noise level generated by these temporary activities would bias the description of the area's usual noise level. Our only choice is to try again at a different time or day.

In any case, always be sure to record the time when you made the measurement. The RNLE must have this information to do a correct noise analysis.

3. Measurement Method

Let's assume the site and time have been selected and the sound level meter is operating properly. Now what? If we are near a road the needle on the meter swings up and down as vehicles pass by. Do we read it when the car or truck is 10 ft down the road or when it is right in front of us? What do we do when no vehicles pass by? The noise at a site varies continuously with time -- that is, at any particular time, there is a certain sound level. This sound level changes continuously. Since sound varies with time, it would be best to take measurements as a function of time. By this we mean that we select a time interval -- say 10 seconds -- and every 10 seconds we read the meter whether it is noisy or quiet, or if a vehicle is or is not nearby. The sound level is recorded each time and after a sufficient period we will have accumulated a number of readings. We can then analyze these in some way to obtain the existing noise level at the site.

4. Data Recording and Reduction

At each 10-second interval, when the meter is read, a value for the sound level is obtained. How do we handle these data and reduce them to a meaningful form? We could write down each reading. An easier method would be to check off the readings as we measure them, on a form having preprinted values on it. Then all that would be necessary would be to put a check near the appropriate value each time it occurs.

This brings us to the question of how many readings we take; also, what do we do with them? FHWA currently states its design noise levels in FHPM 7-7-3 on the basis of a quantity called L_{10}. This is the noise level exceeded for 10 percent of the measurement period. L_{50} and L_{90} are also used in some computations, and are the sound levels exceeded 50 and 90 percent of the time period. How do we find these quantities?

Suppose we have obtained the set of 100 readings shown on the next page. L_{10} is the level exceeded 10 percent of the time and there are 100 readings; 10 percent of 100 is 10. Therefore, L_{10} is the sound level assigned to the row in which the tenth reading occurs. So, starting from the top, we count down the readings until we reach the tenth reading. In this case, L_{10} would be in the second group of readings -- that is, 67 dBA since the tenth reading occurs in that group. Similarly, for L_{50} and L_{90} we count

down from the top to the fiftieth and ninetieth readings. L_{50} would be 64 dBA and L_{90} would be 60 dBA. By using L_{10}, L_{50}, and L_{90}, we can numerically characterize the noise environment at the site where the data was collected.

dBA		Total Readings
68	X X X	3
67	X X X X X X X X (L_{10})	8
66	X X X X X X X X X X X	11
65	X X X X X X X X X X X X X X X (L_{50})	15
64	X X X X X X X X X X X X X X X X	16
63	X X X X X X X X X X X X X X X X	16
62	X X X X X X X X X X X X X X	14
61	X X X X X X X X X X	10
60	X X X X X X X (L_{90})	7
		100

Since we only sampled the noise level once every 10 seconds, rather than continuously, we're not definitely sure that the L_{10} we measured was the actual L_{10} for the entire time period. That is, when we take a set of readings and compute L_{10}, we are actually estimating it based on the set of readings. The larger the set of readings (100, 150, 200, etc.) we take, the more accurate the estimate becomes. This leads us back to the question of how many readings are needed to get an accurate estimate. In order to answer, we first have to determine how accurate we want L_{10} to be.

Say we take 100 measurements and find L_{10} to be 78 dBA. How accurate is the 78 dBA number? Another way of asking how accurate the number is, is to ask how much confidence can be placed in it. If we took 100 readings and got an L_{10} of 78 and then took 50 more and it was still 78, we might feel pretty confident that 78 is a good estimate of L_{10}.

We have decided that for our purposes we want to be 95 percent sure that our measured L_{10} is within $\pm$ 3 dBA of the actual L_{10}. That is, we want to find $L_{10} \pm$ 3 dBA with 95 percent confidence. Through the statistical analysis techniques explained in Appendix D, a table was developed to allow us to check if our data meets this requirement. Its use will be explained in Section III.

We have now looked at the what, where, when, and how of measuring existing noise, and this concludes our general discussion. What remains are the specific field test methods we will use when measuring existing noise.

III. NOISE FIELD TEST METHODS

A. Method 1: Measuring Existing Noise Level by the Check-off Method

1. Scope

This test method prescribes procedures for measurement of existing noise levels, using the Bruel and Kjaer (B&K) Type 2206 precision sound level meter. Instructions for documentation are included. (For those regions using the B&K Type 2205 meter, all procedures apply but attention should be paid to equipment limitations, possible differences in calibration, etc.)

2. Equipment

a. Equipment Required

1. B&K Type 2206 precision sound level meter with Type 4148 condenser microphone.
2. B&K Type 4230 calibrator.
3. Windscreen.
4. Wind velocity meter.
5. Extension cable.
6. Tripod.
7. Clipboard and counter.
8. Sling psychrometer.
9. Stopwatch.
10. Spare batteries.
11. Data and cover sheets (BR320a, BR319a).

b. Equipment Descriptions

1. Sound Level Meter with Condenser Microphone

This meter is a battery-operated precision instrument used to determine SPL in dB (Fig. 4). Its features and controls are as follows:

a. Power Switch

This is a four-position switch marked "off," "fast," "slow," and "batt." "Off" is self-explanatory, "fast" and "slow" refer to how quickly the meter responds to an incident sound wave, and the "batt" position allows the battery to be checked.

b. Range Switch

This is turned to change the reading range of the meter. The range indicator window on the meter shows the range value selected. The meter scale (Fig. 5) has a range of 20 dB. When the needle points to the right of the line beneath the range indicator window, the sound level is the meter scale reading plus the figure in the window. Readings to the left of the line under the window are subtracted from the figure in the window. It is best to attempt to keep the needle in the positive portion (e.g. the 75-dB reading in Fig. 5) since this is easier to read and more accurate.

c. + 10 dB Button

This increases the range of the meter face by automatically adding 10 dB to whatever value is in the range indicator window.

d. Sensitivity Adjustment

This small recessed screw will change the meter's needle position for calibration. Do not press screwdriver in hard.

e. Weighting Network Selector

This should be set on "A" at all times.

f. Microphone

This precision condenser microphone (Fig. 6) can be unscrewed and removed from the meter. Take care not to damage the contacts when removing it. Also, do not remove the grid on top of the microphone at any time. If the meter and microphone are taken to

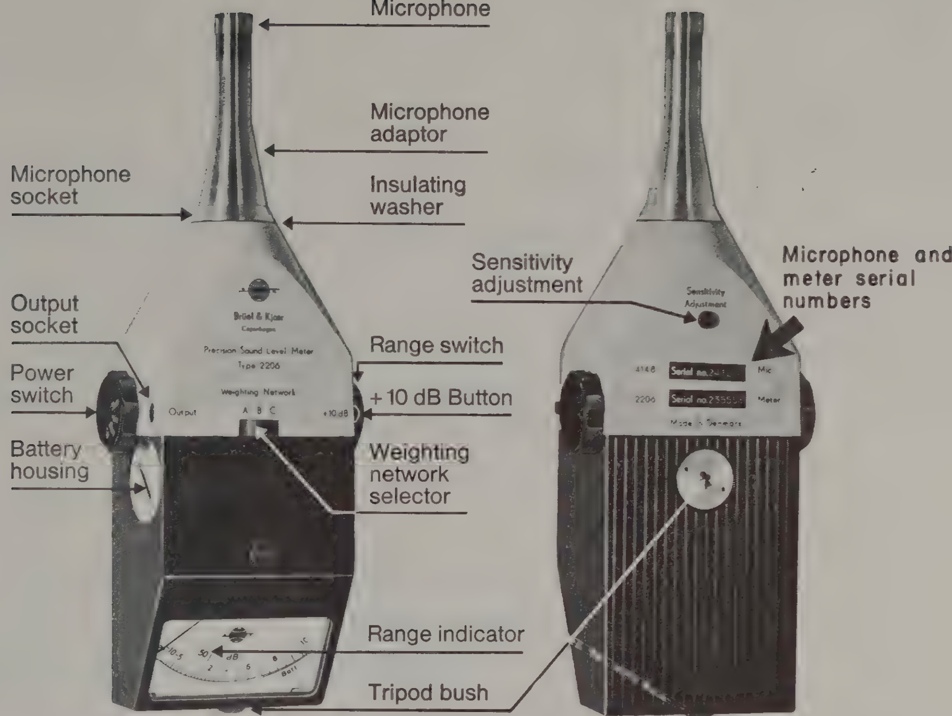


Figure 4. Front and back views of the sound level meter and microphone.

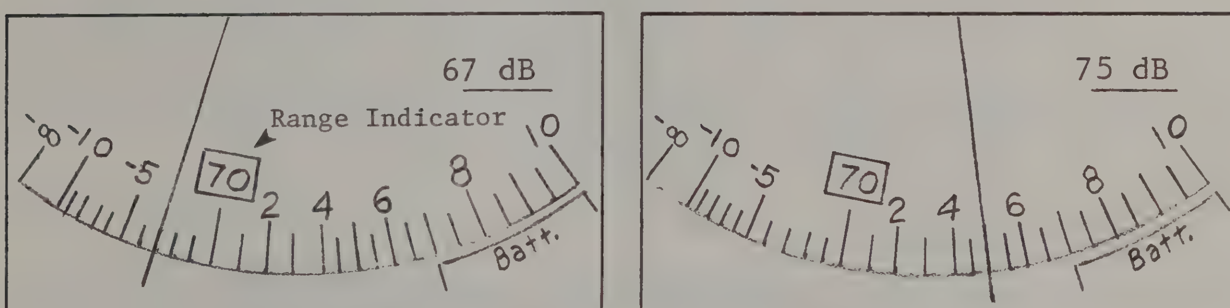


Figure 5 (above). Meter scale at two decibel levels.

Figure 6 (left). Condenser microphone.

a site inside a warm vehicle on a cold day, condensation may form when the microphone is set up outside. Under such conditions, transport the microphone and meter in your car's trunk.

2. Calibrator

This is used to calibrate the sound level meter. The calibration signal for the Type 2206 meter is 93.8 dB.

3. Windscreen

This round foam ball is placed over the microphone to eliminate noise caused by wind blowing across it. It is effective up to 12 mph, at which speed measurements are to be discontinued. Always use the windscreen, even on still days, since it also protects the microphone from dust.

4. Wind Velocity Meter

Instructions for use are printed on the back of this meter: "To use, face the wind. Hold meter in front of you in vertical position and with scale side toward you. Do not block bottom holes. Height of ball indicates wind velocity. For high scale, cover hole at extreme top with finger." Take wind velocity readings at the beginning of each measuremnt period.

5. Extension Cable

Always use an extension cable. It keeps the bulk of the meter and operator from causing a reflection of sound waves, thus affecting the reading. It also allows the operator to sit away from the tripod during readings. The cable connects the meter to the microphone. Do not touch any of the contacts, and keep them as clean as possible.

6. Tripod

Support the microphone on the tripod 4 to 5 ft above the ground.

7. Clipboard and Counter

A legal-size clipboard is supplied with a counter attached. The counter can be used to keep track of the number of readings or to aid in vehicle counts.

8. Sling Psychrometer

Noise cannot be measured when the relative humidity rises above 90 percent. Higher humidity causes condensation on the microphone, rendering it useless until it dries. The psychrometer thus is used to determine relative humidity. The manufacturer's operating instructions are reproduced on the next page. Measure relative humidity twice daily, usually in the morning and afternoon.

9. Stopwatch

Use for readings every 10 seconds.

c. Calibration of the Sound Level Meter

The calibrator has a calibration signal of 93.8 dB at 1,000 Hz. When the calibrator is placed on the microphone, the meter should read 93.8 dB. If it does not, adjust the calibration as follows:

1. Set the range indicator on 90 dB, warm up for 1 to 2 minutes, and check that the microphone and adapter are firmly screwed on.

2. Turn the power switch to "batt" and check the battery. The needle should swing to the red portion of the meter window. If it does not, replace the meter battery.

3. Turn the power switch to "slow."

4. Place the calibrator on the microphone. Be careful not to damage the plastic adaptor on the calibrator.

5. Press the button on the calibrator.

6. Adjust the meter to read 93.8 dB by turning the sensitivity adjustment screw on the back of the meter with the small screwdriver provided in the meter box. Do not touch the zeroing screw on the meter front.

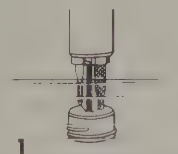
7. The calibrator will automatically turn off after about 1 minute. If the signal lasts only a few seconds, replace the calibrator battery as follows:

    a. Remove the black leather case.

    b. Unscrew the bottom black part of the calibrator housing.

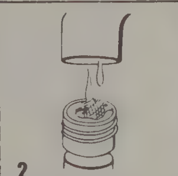
    c. Unsnap the contacts to the battery. Pry the metal clips off. Do not pull on the plastic; this will break the wires.

Remove cap; immerse end of body, to saturate wick.



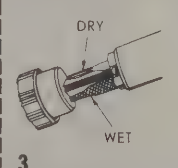
1

Fill psychrometer reservoir with water. Replace cap.



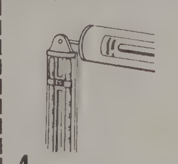
2

Be sure — wick covers "wet" bulb . . . other bulb is dry.



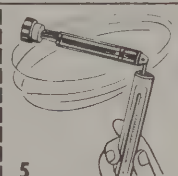
3

Pull body from tube until body hangs free.



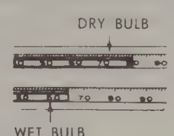
4

Use tube as handle; whirl body about 1 ½ minutes.



5

Read wet and dry bulb thermometers; replace body in tube.

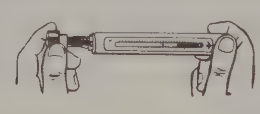


6

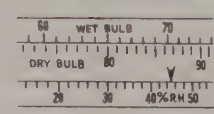
INSTRUCTION DRAWING
Do not use for ordering parts

•

See Parts List on Last Page



7 Set thermometer readings on upper two calculator scales.



8 Read relative humidity % indicated by arrow.

OPERATION

Before using, WICK (A) should be thoroughly saturated with water. Remove END CAP (B) and immerse PSYCHROMETER BODY (C) up to mercury reservoir on the thermometers until WICK is thoroughly wetted. Fill END CAP with water and replace; tighten just enough to prevent leakage.

To use:

1. Be sure WICK (A) is wet and covers mercury reservoir on WET BULB THERMOMETER (D). Be sure mercury reservoir on other THERMOMETER (F) is dry.
2. Pull TUBE (E) clear of BODY so BODY can swivel.
3. Holding TUBE, whirl body two to three revolutions per second (120 to 180 RPM).
4. Continue whirling until temperatures stabilize (1 ½ minutes is usually ample).
5. Immediately read WET BULB THERMOMETER (D) and then DRY BULB THERMOMETER (F). (See application instructions.)
6. Set wet and dry bulb temperatures opposite each other on slide rule type calcuator scales, sliding BODY into TUBE as required.
7. Read % R.H. (per cent relative humidity) indicated by arrowhead on lower scale.

APPLICATION

Wet bulb temperatures should be read first and as quickly as possible for highest accuracy. Delay in reading may cause error. In addition, the wick must be kept clean, saturated with water, and whirled long enough to stabilize temperatures.

Range of the psychrometer is from 10% to 100% R.H. for dry bulb temperatures of 30° to 100°F. or −5° +50°C.

In addition to the above instructions, barometric pressure and other factors will influence exact relative humidity determinations to a very minor degree. For precise work, use psychrometric chart or set of tables such as W.B. No. 235 "Psychrometric Tables for Obtaining the Vapor Pressure, Relative Humidity, and Temperature of the Dew Point" which can be purchased from Superintendent of Documents, United States Government Printing Office, Washington, D. C. However, accuracy of the Psychrometer is satisfactory for all except most exacting work.

MAINTENANCE

WICK (A) should be kept clean; when dirty, cut off below WET BULB THERMOMETER (D) and pull clean section out of END CAP (B) and slide over bulb on WET BULB THERMOMETER.

WICK REPLACEMENT KIT may be purchased separately (refer to parts list). One or two extra WICKS may be kept in END CAP and will help retain moisture longer. Pack WICKS loosely to allow thorough water saturation and ample water supply to WET BULB THERMOMETER.

THERMOMETERS (D) and (F) are replaceable by backing off SCREWS (G) and loosening THERMOMETER CLIPS (H). To separate BODY (C) and TUBE (E), drive ROLL PIN (I) out of eye in PLUG AND SWIVEL ASSEMBLY which then may be slid out back end of TUBE.

d. Replace the battery with a new 9-volt battery.

e. Re-snap the contacts, replace the housing, and return the unit to its case.

The calibrator's leather case is for protection and should be left on except when changing batteries. It protects against dust and the effects of instantaneous temperature changes, as when holding a cold instrument in a warm hand while calibrating. The calibrator has an adapter in the front opening to allow calibration on ½- or 1-in. microphones. Be careful that this adapter does not fall out and become lost. Use only a B&K calibrator on a B&K meter.

d. Maintenance and Repairs

The sound level meter microphone and calibrator are precision equipment and should be treated accordingly. If they fail to operate properly, return them to the Noise Measurement Unit of the Materials Bureau at the Albany Main Office, either by courier (if available) or by United Parcel Service. (Do not send by parcel post.) When shipped to the region from Albany, the equipment is accompanied by a receipt; check to be sure all that is supposed to be shipped is actually included in the package. When the equipment is returned to Albany, return the receipt, and note if any equipment was lost or broken. Keep each set of equipment together -- don't mix and match with other sets, as that makes it more difficult to keep track of equipment.

3. Test Procedure

The method to be used to determine noise levels was developed by Bolt Beranek and Newman, Inc., and is referred to as "the check-off method." The object is to provide a statistical estimate of L_{10} ± 3 dBA with 95-percent confidence. This means we can be 95-percent sure the actual L_{10} for the site is within ± 3 dBA of the L_{10} we compute from the measurements. The ± 3 dBA are termed "confidence limits" for L_{10}. The following procedure details the steps necessary to obtain acceptable measurements using this method. The measurement team will normally consist of at least two Certified NMTs. The duties of reading the meter, checking off the readings, and counting traffic should be divided between them in a way assuring that all duties are performed. For sites located near high-volume roads or intersections, other personnel may be needed to count traffic. RNLEs should be aware of such a possibility and plan accordingly.

1. Check to see that the meter is operating before going into the field. If the battery has been removed, a standard 1.5-volt size "C" cell should be inserted. An alkaline-type battery is preferred and will give up to 10 hours of meter service. To replace the battery, use a coin to unscrew the battery housing, located on the left side of the meter. Insert the battery with the positive contact outward, and replace the battery housing.

2. Obtain weather data (wind velocity, relative humidity, precipitation) and fill in appropriate information on the BR 320a data sheet (instructions for its completion are given later in this section on pp. 30-32). Operation of the wind meter and psychrometer were described on p. 20. The sound meter's operating temperature range is from 14 to 122 F. Discontinue operations if temperatures are lower or higher, if relative humidity exceeds 90 percent, or if wind velocity is greater than 12 mph.

3. Remove the meter from the box.

4. Turn the power switch to "batt." Check that the pointer lies within the red "batt" mark on the meter scale; if not, the battery should be replaced. Turn the meter off after the battery's condition is verified.

5. Set up the tripod. Attach the microphone extension cable between the meter and microphone, and clamp the microphone to the top of the tripod. Orient the microphone vertically 4 to 5 ft above the ground.

6. Set the range switch to a high value (above 90 dB), to avoid overloading when switching the meter on. The range switch position appears in the window on the meter scale.

7. Turn the power switch to position "slow." Unless otherwise directed, make all measurements with "slow" response.

8. Allow 1 to 2 minutes for the circuits to warm up.

9. Select Weighting Network A with the weighting network selector. Take all readings with A-weighting.

10. Calibrate the meter as described on p. 21.

11. Turn the range switch down until the meter needle reads on the scale between the range indicator window and the + 10 dB mark.

12. Estimate the range within which the noise level fluctuates and assign appropriate values to the noise level lines on the data sheet (BR 320a).

13. Note starting time and at the prescribed interval (10 seconds) glance at the meter. Read the meter at that instant to avoid a biased reading. Try not to anticipate what it will be -- just note the reading as it occurs.

14. Record the A-level reading on the BR 320a data sheet as a checkmark on the appropriate horizontal decibel line, working from left to right within each line as shown on pp. 27-9.

15. Simultaneously keep count of the numbers of cars and trucks passing the measurement site if the location is close to or within sight of a highway.

16. If a disturbance occurs that is not considered representative of the existing level being measured, note it on the data sheet. Use a symbol such as A for airplane or T for train instead of a check (see example 1 on p. 27).

17. After 100 readings, test them by the criteria given in the next section. If they meet those criteria, then the measurement is complete. If not, then take another 50 readings and test them, and repeat as necessary up to a maximum of 250 readings.

18. At the conclusion of the test, re-check the calibration of the meter, re-check the battery, and record these results on Form BR 320a. If the meter is not reading 93.8 $\pm$ 0.5 dB on re-check, repeat the measurements.

19. Note the time finished and record it on the data sheet. Re-check the calculations and be sure that the data sheets are completed.

4. Sample Criteria

After the first group of 100 readings and after each additional group of 50 readings, the following test is made:

1. Counting down from the top of the BR 320a data sheet (and from left to right along each line), circle the test readings shown in the following table (which is also reproduced on the back of BR 320a):

Total Readings	Upper Limit	L_{10}	Lower Limit	Allowable Skew
100	5	10	17	1
150	8	15	23	1
200	12	20	29	1
250	16	25	35	1

   For instance, after taking 100 samples, circle the fifth, tenth, and seventeenth samples from the top. These three constitute the L_{10}, flanked by its upper and lower limits.

2. The acceptable limits are $\pm$ 3 dBA or less.

3. In determining if the 100 readings meet the criterion of $\pm$ 3 dB or less, a process called skewing is allowed. By this process,

the upper and lower limits can be shifted by the number of samples listed in the "Allowable Skew" column. The shift can be either up or down. For example, if the criterion is not met (after 100 samples) by the fifth, tenth, and seventeenth samples, the allowable skew according to the table is one sample. Thus the criterion can be tested with the fourth, tenth, and sixteenth samples (skewing up one sample) or with the sixth, tenth, and eighteenth samples (skewing down one sample). Although this skewing procedure will not change the L_{10} value, nor the number of samples between the upper and lower confidence limits, it can sometimes provide the necessary accuracy without requiring further sampling.

Skewing up or down in BR 320a refers to the direction of change as just explained. Note that using the fourth, tenth, and sixteenth samples from the top, instead of the fifth, tenth and seventeenth would be skewing up, not down, and would be so entered on BR 320a. Using the sixth, tenth, and eighteenth samples would be skewing down, and should be so entered.

If the criterion is not met after skewing, take an additional 50 samples. The maximum to be taken at any one site is 250. If the criterion is still not met after 250 samples, note this at the bottom of the data sheet.

Even if the criteria is met after 100 samples, skewing should still be used if it will increase the accuracy of the results. For example, say the resulting limits for L_{10} after 100 samples without skewing are 75 +3 -3 dBA. Additionally, say that by skewing down, the limits would change to 75 +2 -3 dBA. The results should be reported as 75 +2 -3 dBA and skewing down indicated on the data sheet. If the accuracy can be increased through skewing, it should be done even if the criteria would be met without it.

4. When the test criterion has been met (or 250 samples taken and the criterion not met), calculate L_{50} and L_{90}. The former is the noise level exceeded 50 percent of the time and is represented by the 50th percentile reading from the top. Thus with 100 readings it's the 50th from the top, and so on. L_{90} is the noise level exceeded 90 percent of the time and is represented by the 90th percentile reading from the top. L_{90} for 100 readings is the 90th from the top; for 150 it is the 135th from the top.

   L_{50} is counted from the top. A common mistake is to count up from the bottom of the data to find L_{90}. For example, with 100 readings, counting up to the tenth reading from the bottom will give you the 91st from the top, not the 90th.

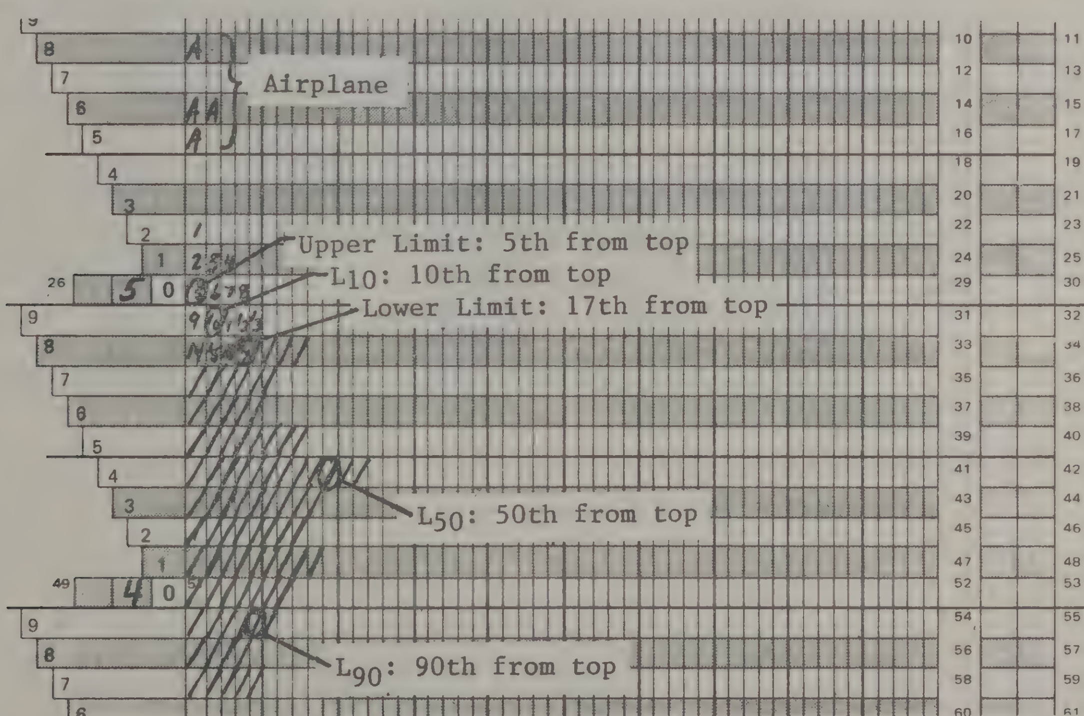
   A simple rule in finding L_{90} is to count up from the bottom of the data the same number of readings listed under L_{10} in the table, and then count up one more -- this is L_{90}. For instance,

for 150 readings, the table gives the 15th reading as L_{10}. To find L_{90}, count up from the bottom of the data 15 readings plus one.

The examples on this and the next two pages should help explain these rules.

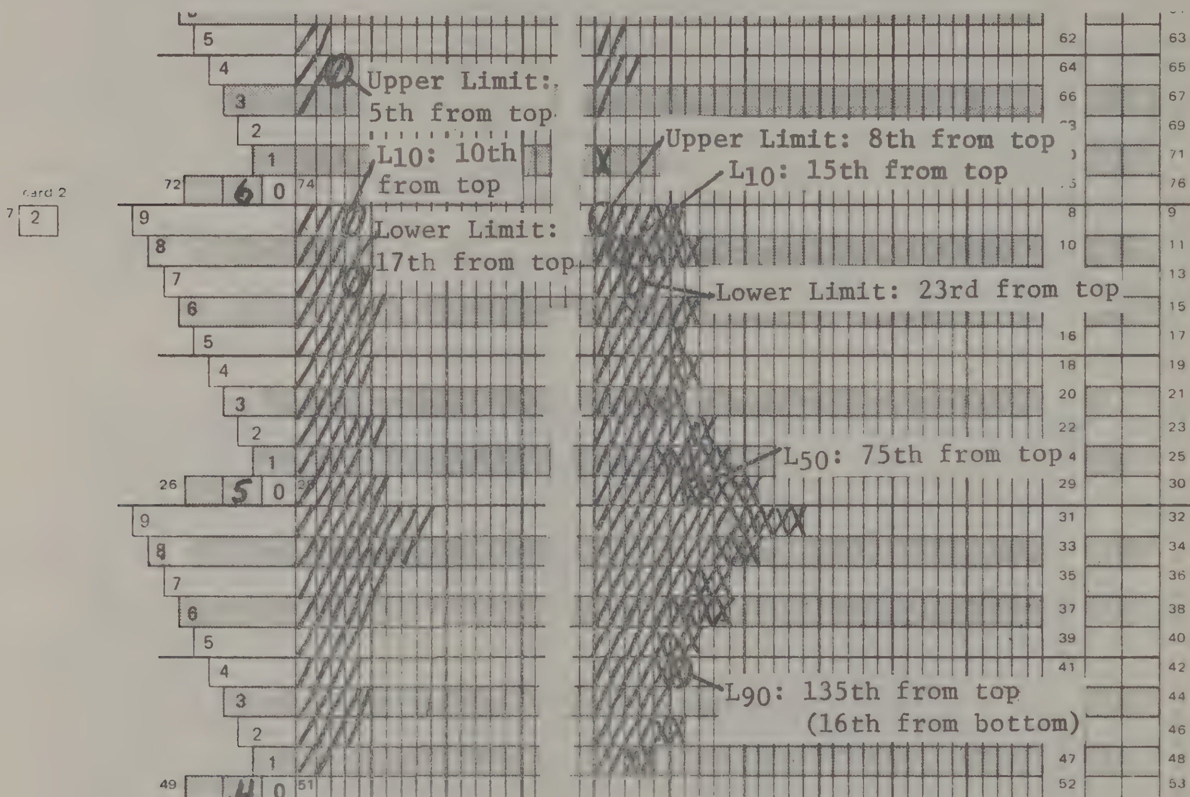
EXAMPLE 1   Criteria Met After 100 Samples

At this site, 100 readings were taken, ranging from 37 to 52 dB. (The four airplane readings, in this case, were not considered "representative" of the site and were not counted.) Counting down from the top, the highest reading is 52 dB the second and third both 51 dB, etc. as numbered on the sheet. In this case the tenth reading represents L_{10}, which is 49 dB. The fifth reading is the upper limit or 50 dB, and the seventeenth the lower limit at 48 dB. Since the difference between L_{10} (49 dB) and each limit is 1, L_{10} can be expressed as 49 ± 1. No further readings are necessary, as ± 1 is well within the ± 3 dB limits required. L_{50} is the 50th reading from the top at 44 dB and L_{90} the 90th at 39 dB.



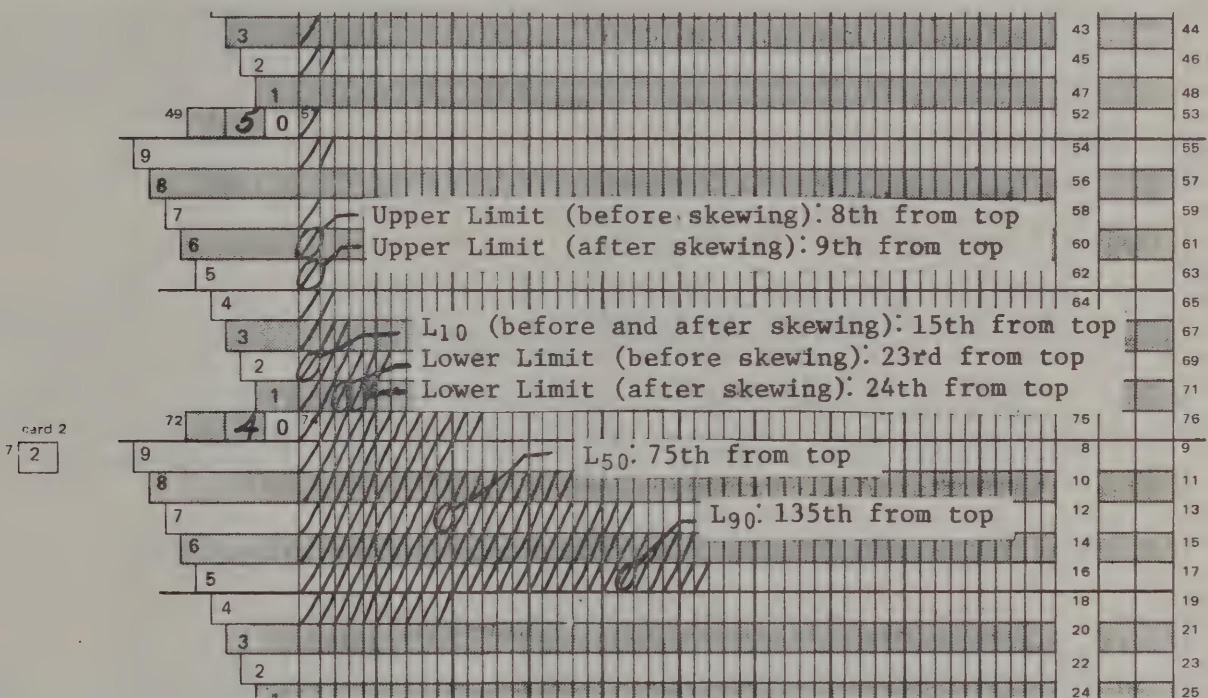
EXAMPLE 2 Criteria Not Met After 100 Samples; 50 More Were Taken

Here 150 samples were necessary. The first 100, represented by slashes, resulted in an L_{10} of 49 +5 -2 dB (54 being the upper limit, and 47 the lower), which is not within the limits of $\pm$ 3 dB. Even after skewing down, the limits would only be +4 -2. Fifty more readings were then taken and are represented by x's. The upper limit, L_{10}, and lower limit (the 8th, 15th, and 23rd readings) are now 49, 48, and 47 dB, respectively. The L_{10} limits (48 +1 -1 dB) are now within requirements.



EXAMPLE 3   Criteria Met After Skewing

In this case, 150 readings were taken. The upper limit, L_{10}, and lower limit are 46 dB (8th from the top), 42 dB (15th from the top), and 41 dB (23rd from the top). These data can be skewed down by shifting the upper limit to 9th from the top (44 dB), and the lower limit to 24th from the top (still 41 dB). L_{10} remains 42 dB and is now 42^{+3}_{-1} instead of 42^{+4}_{-1}.



5. Noise Data Forms

The two forms the NMT team will be concerned with are the Noise Measurement Cover Sheet (BR 319a) and the Noise Measurement Data Sheet (BR 320a). The first contains common identifying information that remains the same for a number of test sites (up to six sites) and also an area for comments on individual site locations and/or descriptions of noteworthy conditions relating to the measurements. The second is for recording actual test data; the coded tallies of measurements; L_{10}, L_{50}, and L_{90} values; and other information unique to a particular test and time. The BR 319a and 320a comprise the hard copy of the measurement data to support the EIS's noise analysis. They will be used to transmit these data to the Main Office Noise Unit for keypunching and entry into the permanent Electronic Data Processing (EDP) Bureau computer file.

a. General Rules for Coding Forms

Information for keypunching must be written neatly and accurately. One character should be entered in each box provided. Use no special characters, roman numerals, or punctuation. Allowable characters include capital letters A through Z and the numbers 0 through 9. To differentiate between the letter O (oh) and the number 0 (zero), place a slash through the letter in this manner: Ø. The rules below give proper coding procedure.

1. Enter only one character (letter or number) in each box.

   Example: For May 8, 1976

18 Month 19			20 Day 21			22 Year 23	
0	5	/	0	8	/	7	6

2. Decimals are printed on the forms; print only numbers in the boxes.

   Example:

7	PIN							15
4	2	1	8.	1	2.	0	0	0

3. Always record numbers from right to left in each group of boxes.

   Example: Enter a single digit as follows | 0 | 0 | 6 |

4. If an error occurs, carefully erase the entry and place the correct data on both sheets of the form or draw a horizontal line through the entry, and record the correct data above the boxes involved.

   Example:

3	0	4	0
~~3~~	~~0~~	~~0~~	~~4~~

5. If an item is incorrectly circled, draw a diagonal line through the error and circle the correct item.

   Example: 57 Day (Circle One)

Sun	Mon	Tues	Wed	Thur	Fri	Sat
1	~~2~~	3	4	5	6	7

6. Record starting and finishing times in a 24-hour fashion.

   Example: For 3:45 p.m. 30 (24 Hour Clock) 33 | 1 | 5 | : | 4 | 5 |

7. Enter a slash through the letter "O" to distinguish it from a zero.

   Example: | S | Ø | U | T | H |

b. <u>Coding the Cover Sheet (BR 319a)</u>

   1. Enter the PIN, region, date, region's work order number (if any), city or town, and county. Use abbreviations when necessary.

   2. Print the project name on the line provided and indicate the day, types of attachments, NMT names and numbers, and equipment serial numbers in the boxes provided.

   3. At each measurement site, indicate the point numbers, starting time, finishing time, and any noteworthy information concerning the site location and any special conditions relating to the measurements.

Note the six-digit cover sheet number stamped at the top right corner of the form. This number should be recorded on each of the <u>data sheets</u> (BR 320a) related to this cover sheet.

c. <u>Coding the Data Sheet (BR 320a)</u>

   1. Record the meter serial number, date, cover sheet number, test interval, PIN, weight, response, precipitation, wind speed, relative humidity, temperature, and point number at the lower right of the form.

   2. Diagram the measurement site (including critical distances) at the lower left of the form.

   3. Indicate an acceptable initial battery check by placing a check (√) in the box labeled "I."

   4. After calibrating the sound level meter, record the initial calibration values. (This should be 93.8 dB for the 2206 meter and 4230 calibrator.)

   5. Determine the general range of noise levels existing at the site and indicate this range on the data sheet in the boxes to the left of the check-off grid.

   6. Record the starting time and begin noise level measurements at the proper time interval. Indicate these readings on the check-off grid (see <u>Data Recording and Reduction</u> on p. 14).

c. <u>Coding the Data Sheet (BR 320a)</u>

7. After completion of the noise measurements, record the time finished at the bottom of the sheet.

8. Count up the check marks on the check-off grid and fill in the subtotals and total number of readings.

9. Record the results of the final battery check and calibration. <u>If these are within the specified limits</u>, record L_{10}, the L_{10} limits, L_{50}, and L_{90} at the bottom of the form. (If the battery check and/or calibration value falls outside the specified limits, the equipment and, thus the data are questionable.)

When the field work is completed for a project, the RNLE will send the white original cover sheet and the associated white original data sheets (originals being required by the Main Office EDP Bureau for keypunching), along with a map showing the locations of sites actually measured in the field, to the Main Office Noise Measurement Unit.

Typical examples of a coded BR 319a and BR 320a are shown on the next two pages.

BR 319a (6/75)

NOISE MEASUREMENT COVER SHEET

No. 000502

Card 1

PIN (7–15)	Region (16–17)	Month (18–19)	Day (20–21)	Year (22–23)	Region Work Order No. (24–28)
1310·02·111	01	07	28	75	

City/Town (29–44)	County (45–56)
CØLØNIE	ALBANY

Project Name: I 66 - Crosstown Arterial

57 Day (Circle One): Sun 1, Mon 2 (circled), Tues 3, Wed 4, Thur 5, Fri 6, Sat 7

58 Circle 59 Each 60 Type 61 or 62 Attachment: Traffic T (circled), Maps M (circled), Pictures P, Sketches S, Other O — list

78: 1

Card 2

Crew Member	Name	NMT Cert. Number
1st Crew Member	Orlando Picozzi	M-002
2nd Crew Member	Paul Kelly	-107
3rd Crew Member	Tom Nelson	T-005
4th Crew Member	Brian Bowson	-53

Meter No.1 Serial No. (23–28)	Mike No.1 Serial No. (29–34)	Calib No.1 Serial No. (35–40)
17495	46327	952716

Meter No.2 Serial No. (41–46)	Mike No.2 Serial No. (47–52)	Calib No.2 Serial No. (53–58)
213716	234667	861455

Reviewed By: E. Skoglund

Date: 7/30/75

78: 2

Card	Point No. (7–9)	Time Started (30–33)	Time Finished (54–57)	Location and Description (10–29)	(34–53)	(58–77)	78
Card 3	A2	13:35	14:05	100 FT SØ ØF BRAGG	250 FT W ØF CLINTØN	AFTERNØØN RUSH	3
Card 4	A9	14:45	15:20	CRAIG SCHL PLAYGRND	50FT FRØM NØTT ST	SCHØØL IN SESSIØN	4
Card 5	A10	16:05	16:30	I90 350FT PAST EX10	WESTBØUND		5
Card 6	B12	16:55	17:35	WØLF RD 500FT FRØM	SHAKER RD 1000FT SØ	NS RNWY ALB CO ARPT	6
Card 7	A2	17:50	18:20	EVENING AMBIENT			7
Card 8		:	:				8

BR 320a (6/75)

NOISE MEASUREMENT DATA SHEET

card 1: 1

decibel range	Subtotal
89	
88	
87	
86	
85	
84	
83	
82	
81	
80	
79	
78	
77	
76	
75	
74	
73	1
72	2
71	3
70	4
69	7
68	9
67	10
66	10
65	9
64	8
63	7
62	7
61	6
60	6
59	5
58	3
57	2
56	1
55	
54	
53	
52	
51	
50	
49	
48	
47	
46	
45	
44	
43	
42	
41	
40	

card 2: 2

Batt Check (√): I √ F √ | Initial Calib 1000 Hz: 93.8 | Final Calib 1000 Hz: 93.7 | Meter Serial Number: 213716 | Total: 100

card 3: 3

Diagram

Field	Value
Month / Day / Year	07 / 28 / 75
Cover Sheet Number	000502
Test Intvl(sec)	10
PIN	1310-02-111
Weight	A
Response (Circle)	Fast F / Slow (S) — S circled
Precip (Circle)	No (N) / Yes Y — N circled
Wind (MPH)	08
% Rel. Humidity	76
Temp. (°F)	81
Skew (Circle)	None (0) / U↑ / D↓ — 0 circled
Start (24 Hr. clock)	13:35
L10	70-1-1
L50	65
Finish (24 hr. clock)	14:05
L90	59
Point Number	A2

6. Special Considerations

General sites for noise measurements will usually be chosen and located on a map by a design or planning engineer. The technician team then takes the map to the sites and picks the best location to set up equipment. If the site of interest is near a house or school, place the meter in the yard where there is likely to be human activity. The object is to measure noise from all sources to which the occupant is normally exposed -- not just traffic noise. Therefore, the meter should not be set up next to the road, where traffic noise is dominant. Also avoid billboards, sides of buildings, and other large reflecting surfaces. Noise tends to be reflected back to the microphone, increasing the noise level. It is sometimes necessary, however, to locate near a reflective surface; this should be done if so specified by the RNLE.

Sometimes it is difficult to determine whether a sound is characteristic of a site. For example, an airplane may fly over during a measurement period. Perhaps only one flies over each day and you caught it, or perhaps they fly over frequently. In the former case, note the readings, but don't use them for calculating L_{10}. In the latter, count the airplane as typical noise. A tractor operating on a farm might be considered typical noise, but one should try to return to the site to measure when it is not operating. In any event, the fact that a tractor was operating should be noted on the cover sheet.

As for when to measure, we are limited to whenever the technician team gets to the site. It is impractical to try to hit each site when it is noisiest. Rush-hour traffic is not necessarily the noisiest condition -- heavy truck traffic may not appear until night-time. The best we can do is to project noise levels from measurements accompanied by traffic counts. The fine points of site selection, disturbances, and other measurement-related problems are often left to the discretion of the NMT team. In an unusual situation, however, the RNLE should be consulted to resolve the problem. Additional support may be obtained (calling collect, if necessary) from the Main Office Noise Unit in Albany; use the state tie-line access code or Area Code 518, and then dial 457-4285. This unit is also interested in your comments on special problems and their resolution.

7. Noise Measurement Technician's Checklist

a. Equipment

1. Sound level meter with microphone.
2. Calibrator.
3. Windscreen.
4. Wind velocity meter.

5. Extension cable.

6. Tripod.

7. Clipboard and counter.

8. Sling psychrometer.

9. Stopwatch.

10. Spare batteries.

11. Coding sheets (BR 319a and BR 320a).

b. Procedure

1. Check that the meter is operating before going into the field.

2. Measure and record wind speed -- do not take noise measurements if the wind is over 12 mph. Check relative humidity twice a day; discontinue operations if it exceeds 90 percent. Discontinue noise measurements if the temperature falls below 14 F or exceeds 122 F.

3. Check the meter battery.

4. Set up the meter, tripod, and extension cable.

5. Calibrate the meter -- 93.8 dB before measuring -- and re-check it after each site measured. Repeat the measurement if it is not registering in the proper range (i.e., between 93.3 and 94.3 dB.)

6. Take noise readings using A-weighting and slow response. Note starting time.

7. Calculate L_{10}, L_{50}, and L_{90}. Note finishing time.

8. Fill out the data sheet completely before leaving the site.

9. Have your partner check your calculations.

APPENDIX

A. Glossary of Terms
B. Forms List
C. Equipment List
D. Method of Determination of Confidence Limits and Coefficients
E. References for Further Reading
F. Mathematical Statement of Sound Pressure Level and Decibel Addition of Two Equal Sources
G. Excerpts from Federal-Aid Highway Program Manual 7-7-3

A. Glossary of Terms

A-Weighting: adjustment of the amplitude of a sound wave based on frequency designed to approximate frequency response of the human ear.

Ambient Noise: all noise existing at a site.

Amplitude: for a wave, the amount of displacement from an equilibrium level.

Attenuation: a reduction of wave amplitude.

Calibrator: an electronic device used to generate a known sound level.

Car: any four-tire, two-axle vehicle, including sports cars, pickup trucks, and small vans.

Characteristic Sound: a sound representative of a measurement site.

Check-off Method: a method for measuring ambient noise by taking readings at a prescribed time interval, ranking them, and analyzing them statistically.

Confidence Limits: the upper and lower values of the range within which a given percent probability applies; for instance, if the chances are 95 out of 100 that a sample lies between 10 and 12, the 95-percent confidence limits are said to be 10 and 12.

Cycle per Second: a complete wave occurring in 1 second (see Hertz).

Data: measurements taken as bases for an investigation.

dB: abbreviation for decibel.

dBA: abbreviation for decibel utilizing the A-weighting network.

Decibel: the units of amplitude measurement for sound pressure level, defined as

$$SPL_{dB} = 10 \log \left(\frac{P}{P_0}\right)^2 \quad \text{or} \quad SPL_{db} = 20 \log \left(\frac{P}{P_0}\right)$$

where P = disturbance pressure, and

P_0 = reference pressure.

Equilibrium Level: the reference or undisturbed level for a particular quantity; for sound, the equilibrium level is atmospheric pressure.

Frequency: the number of time a wave repeats within a given period.

Hertz: one cycle per second, abbreviated Hz.

Humidity: the percent of moisture in the air.

L_{10}, L_{50}, L_{90}: sound levels exceeded, respectively, 10, 50, and 90 percent of the time.

Logarithm: the power to which a base number is raised to equal a given value; for example, $10^2 = 100$ and $\log_{10} 100 = 2$.

Masking: the effect whereby a sound that is approximately 10 dB or greater than another "drowns out" the lesser sound.

Microphone: an electronic device sensitive to pressure changes, converting them into electrical current.

Noise: unwanted sound.

Pressure: force applied on a given area; some pressure units are pounds per square inch (psi), atmospheres, etc.

Reference Pressure: for sound measurement, this is 20 micronewtons per square meter; -- the smallest pressure the ear can detect.

Sling psychrometer: a device for measuring relative humidity.

Sound: a wave disturbance in an elastic medium, such as air.

Sound Level: weighted sound pressure level measured by a metering device.

Sound Level Meter: a device for measuring sound level.

Sound Pressure Level: in decibels, 10 times the logarithm of the square of the ratio of the disturbance pressure to the reference pressure; it is a measure of the amplitude of a sound wave.

Traffic Mix: percentage of cars and trucks in the total number of vehicles.

Traffic Volume: total number of vehicles in a given time period.

Wave: variation in a medium characterized by frequency and amplitude.

Windscreen: a porous polyurethane sponge material used on a microphone to eliminate wind noise and protect against dust.

Wind Velocity Meter: a device for measuring wind speed.

B. Forms List

1. Form BR 319a: Noise Measurement Cover Sheet.

2. Form BR 320a: Noise Measurement Data Sheet.

C. Equipment List

1. Brüel and Kjaer Type 2206 Sound Level Meter with Type 4148 Condenser Microphone.

2. Brüel and Kjaer Type 4230 Calibrator.

3. Windscreen.

4. Wind Velocity Meter.

5. Extension cable.

6. Tripod.

7. Clipboard with counter.

8. Sling Psychrometer.

9. Stopwatch.

10. Spare Batteries.

D. Method of Determination of Confidence Limits and Coefficients

This method is reproduced in facsimile from Fundamentals and Abatement of Highway Traffic Noise (see Anderson, Miller, and Shadley in Appendix E).

Assume that a total of n statistically independent noise levels l have been measured from the same population. Assume, further, that these noise levels are ordered according to their magnitudes, and let the sequence of these ordered levels be denoted by l_1, $l_2, \ldots l_n$, where the highest measured level is denoted by l_1 and the lowest is denoted by l_n.

Let L_p denote the p*th* percentile noise level as determined by the infinite population from which the n samples have been drawn. L_p is defined by,

$$\int_{L_p}^{\infty} f(l)dl = p, \qquad (1)$$

where $f(l)$ is the probability density function of the noise levels from which the samples have been drawn. Thus, the probability is p that a randomly drawn sample will have a level l higher than the level L_p. The problem is to estimate L_p, for a given value of p, from a finite set of ordered samples l_1, $l_2, \ldots, l_n$.

Assume that n samples have been drawn and ordered as described above. Consider the event $l_r > L_p > l_s$ where $r<s$; that is, the event that the r*th* noise level is higher than L_p and the s*th* noise level is lower than L_p. This event is equivalent to the compound event that exactly r measured levels are higher than L_p *or* exactly r+1 measured levels are higher than L_p *or* ... *or* exactly s-2 measured levels are higher than L_p *or* exactly s-1 mea-

sured levels are higher than L_p. These events are mutually exclusive; therefore, the probability of this compound event is the sum of the probabilities of the individual events. Now, according to Eq. 1, the probability is p that any one noise level measurement is larger than L_p. Since the measured levels are assumed statistically independent, the probability that exactly k of the measured levels are higher than L_p is the probability of exactly k "successes" in a set of n Bernoulli trials, where the probability of the "success" of a single trial is p. In such a situation, the probability of k successes is

$$\binom{n}{k} p^k (1-p)^{n-k} \qquad (2)$$

where

$$\binom{n}{k} = \frac{n!}{(n-k)!k!} \qquad (3)$$

Thus, the probability of the above described compound event is obtained by summing the probabilities (2) for k=r, r+1, ..., s-2, s-1;

that is

$$\Pr\left[l_r > L_p > l_s\right] = \sum_{k=r}^{s-1} \binom{n}{k} p^k (1-p)^{n-k} \qquad (4)$$

Equation 4 expresses the probability that at least r but less than s noise level measurements fall above the level L_p. Notice that at no point have we made any assumptions about the form of the noise level probability density function $f(l)$.

Let us now designate $\Pr\left[l_r > L_p > l_s\right]$ by γ; i.e.,

$$\Pr\left[l_r > L_p > l_s\right] = \gamma . \qquad (5)$$

Then, by definition, γ is the confidence coefficient that the *rth* and *sth* measured levels satisfy the relationship $l_r > L_p > l_s$; l_r and l_s are known as the upper and lower confidence limits for the *pth* percentile noise level L_p.

Table 3.1 lists values of γ for selected sets of values of n, r, and s, where all values listed are for the case where p = 0.10. The values were computed using the right-hand side of Eq. 4.

TABLE 3.1 - CONFIDENCE COEFFICIENTS

Number of Samples, n	Lower Error Limit, r	Upper Error Limit, s	Confidence Coefficient, γ
350	24	46	0.949
350	25	47	0.950
350	26	48	0.944
300	19	40	0.952
300	20	41	0.957
300	21	42	0.955
250	15	34	0.950
250	16	35	0.956
250	17	36	0.952
200	11	28	0.949
200	12	29	0.956
200	13	30	0.952
150	7	22	0.950
150	8	23	0.960
150	9	24	0.955
100	4	16	0.952
100	5	17	0.956
100	6	18	0.932
50	1	10	0.970
50	2	10	0.942

E. References for Further Reading

1. Books on Noise, Acoustics, and Related Problems

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U.S. Environmental Protection Agency. Public Health and Welfare Criteria for Noise. Report 550/9-73-002, 1973.

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2. Periodicals on Noise, Acoustics, and Related Subjects

Applied Acoustics (French; English abstracts).

Journal of the Acoustical Society of America, American Institute of Physics, 335 E. 45th St., New York, N.Y.

Journal of Sound and Vibration, Academic Press, 111 Fifth Ave., New York, N.Y. 10003.

Noise Control Engineering, Institute of Noise Control Engineering, Poughkeepsie, N.Y. 12603.

Noise Control Report, Business Publishers, Inc., Silver Springs, Md.

Noise News, Institute of Noise Control Engineering, Poughkeepsie, NY 12603.

Sound and Vibration, Acoustical Publications, Inc., 27101 E. Oviatt Rd., Bay Village, Ohio 44140.

F. Mathematical Statement of Sound Pressure Level And Decibel Addition of Two Equal Sources

The mathematical statement of sound pressure level in decibels is

$$SPL_{dB} = 20 \log_{10} \frac{P}{P_0}$$

where P = the change from atmospheric pressure caused by the sound wave, and

P_0 = the reference pressure, equal to the smallest pressure the human ear can detect.

As stated earlier, the range of pressures the human ear can detect is very large. Because this is true, the logarithm of the pressure ratio is used. By using a logarithm, we can convert a very large number into a much smaller one. We can then convert the very large range of pressures the human ear can detect into a smaller range of numbers that are easier to deal with, thus making it easier to compare different sounds.

For instance, suppose we had four sound waves, each causing a pressure disturbance 10 times greater than the previous one. In mathematical terms, we couls state this as follows:

Sound Wave 1: $P_1 = 100\ P_0$

Sound Wave 2: $P_2 = 10\ P_1 = 1{,}000\ P_0$

Sound Wave 3: $P_3 = 10\ P_2 = 10{,}000\ P_0$

Sound Wave 4: $P_4 = 10\ P_3 = 100{,}000\ P_0$

Dividing both sides of these equations by P_0, we get:

$$\frac{P_1}{P_0} = 100 \frac{P_0}{P_0} = 100$$

$$\frac{P_2}{P_0} = 1000 \frac{P_0}{P_0} = 1{,}000$$

$$\frac{P_3}{P_0} = 10{,}000 \quad \frac{P_0}{P_0} = 10{,}000$$

$$\frac{P_4}{P_0} = 100{,}000 \quad \frac{P_0}{P_0} = 100{,}000$$

since dividing P_0 by P_0 is equal to 1, just as 2 divided by 2, or 3 divided by 3 equals 1.

Now, SPL is defined in terms of "base 10" logarithms. This means we know that 10 x 10 = 100 -- 10 x 10 is known as 10^2 (10 squared). Similarly, 10 x 10 x 10 = 1,000 = 10^3 (10 cubed). The "base 10" logarithm of a number is defined as the number of times 10 must be multiplied by itself to get the number. For instance,

$$10 \times 10 = 100$$

or

$$10^2 = 100$$

Then

$$\log_{10} 100 = 2$$

Ten multiplied by itself will give 100. Therefore, the base 10 logarithm of 100 is equal to 2. In the same way, then, if $\log_{10} 100 = 2$, then

$$\log_{10} 1{,}000 = 3 \quad (10 \times 10 \times 10 = 1000)$$

Similarly,

$$\log_{10} 10{,}000 = 4 \quad (\underset{1}{10} \times \underset{2}{10} \times \underset{3}{10} \times \underset{4}{10} = 10{,}000)$$

$$\log_{10} 100{,}000 = 5 \quad (\underset{1}{10} \times \underset{2}{10} \times \underset{3}{10} \times \underset{4}{10} \times \underset{5}{10} = 100{,}000)$$

Let's return to our sound waves. The SPL equation says we multiply 20 times the base 10 logarithm of P/P_0. Setting up a table:

Sound Wave	P/P_0	$\log_{10} P/P_0$	SPL_{db}
1	100	2	40
2	1,000	3	60
3	10,000	4	80
4	100,000	5	100

We can see that for a range of pressures from 100 to 100,000 times the smallest pressure the ear can detect, the range in decibels is only 40 to 100. It is much easier to compare numbers from 40 to 100, and plot 40 to 100 on a graph or measuring device, than to plot 100 to 100,000.

Now, as we also said earlier, if two boards are each 10 ft long, the total length of both is 20 ft. However, two equal sound sources producing 70 dB each add up to only 73 dB -- not 140 dB. This is because:

the definition of SPL is decibels is:

$$SPL_{dB} = 20 \log_{10} \frac{P}{P_0}$$

this is the same as

$$SPL_{dB} = 10 \log_{10} \left(\frac{P}{P_0}\right)^2$$

where

$$\left(\frac{P}{P_0}\right)^2 = \frac{P}{P_0} \times \frac{P}{P_0}$$

To prove this, let's assume $P/P_0 = 100$. Then

$$\left(\frac{P}{P_0}\right)^2 = \frac{P}{P_0} \times \frac{P}{P_0} = 100 \times 100 = 10,000$$

Lets put the two equations for SPL side by side:

$SPL_{dB} = 20 \log_{10} \frac{P}{P_0}$	$SPL_{dB} = 10 \log_{10} \left(\frac{P}{P_0}\right)^2$
$SPL_{dB} = 20 \log_{10} 100$	$SPL_{dB} = 10 \log_{10} 10,000$
$\log_{10} 100 = 2$	$\log_{10} 10,000 = 4$
$10 \times 10 = 100$	$10 \times 10 \times 10 \times 10 = 10,000$
$\therefore SPL_{dB} = 20 \times 2$	$\therefore SPL_{dB} = 10 \times 4$
$SPL_{dB} = 40$	$SPL_{dB} = 40$

We can see then that both definitions are the same because they produce the same answer. Let's get back now to our two equal sound sources. Suppose the pressure ratio produced by one source is $(P/P_0) = 10$. Then

$$\left(\frac{P}{P_0}\right)^2 = \frac{P}{P_0} \times \frac{P}{P_0}$$

$$= 10 \times 10$$

$$= 100$$

For two equal sources, the pressure ratio squared will be twice this, or

$$2\left(\frac{P}{P_0}\right)^2 = 200$$

$$SPL_{\text{one source}} = 10 \log_{10} \left(\frac{P}{P_0}\right)^2$$

$$\left(\frac{P}{P_0}\right)^2 = 100$$

$$SPL_{\text{one source}} = 10 \log_{10} 100$$

$$\log_{10} = 2$$

$$\therefore SPL_{\text{one source}} = 10 \times 2$$

$$SPL_{\text{one source}} = 20 \text{ dB}$$

$$SPL_{\text{two equal sources}} = 10 \log_{10} 2\left(\frac{P}{P_0}\right)^2$$

$$2\left(\frac{P}{P_0}\right)^2 = 200$$

$$SPL_{\text{two equal sources}} = 10 \log_{10} 200$$

$$\log_{10} 200 = 2.3$$

(The base 10 log of 200 can be found in any table of logarithms)

$$\therefore SPL_{\text{two equal sources}} = 10 \times 2.3$$

$$SPL_{\text{two equal sources}} = 23 \text{ dB}$$

Thus two equal sources produce only a 3-dB increase in SPL over only one of the sources.

G. Excerpts from Federal-Aid Highway Program Manual 7-7-3

The following paragraphs are taken from Volume 7, Chapter 7, Section 3 of the Federal-Aid Highway Program Manual ("Procedures for Abatement of Highway Traffic Noise and Construction Noise"). They describe what is required for a noise impact analysis and explain the design noise levels. See the Regional Noise Liaison Engineer for a copy of the entire document.

Federal-Aid Highway Program Manual Transmittal 192, May 14, 1976	Vol. 7. Ch. 7 Sec. 3

7. ANALYSIS OF TRAFFIC NOISE IMPACTS AND ABATEMENT MEASURES

   a. In type IA and IB project development, the highway agency shall determine and analyze expected traffic noise impacts and determine the overall benefits which can be achieved by noise abatement measures to mitigate these impacts, giving weight to any adverse social, economic, and environmental effects. The level of analysis may vary from simple calculations for rural and low volume highways to extensive analysis for high volume, controlled access highways in urban areas.

   b. The traffic noise analysis shall be conducted in the following manner:

      1. Identify existing activities or land uses which may be affected by noise from the highway section.

      2. Predict the traffic noise levels for each alternative under detailed study (including the "do nothing" alternative). Steps 3 through 6 of the traffic noise analysis may be eliminated if it is analytically determined (in accordance with steps 1 and 2) that activities or developed land uses are not sufficiently close to the proposed highway improvement to be adversely affected by traffic noise.

      3. Measure the existing noise levels for existing activities or developed land uses. Measurements may not be necessary where it is clear that the existing levels are predominantly from the highway being improved and can be satisfactorily estimated using approved noise prediction methods. The purpose of this noise level information is to quantify the existing acoustic environment and to provide a base for assessing the impact of noise level increases. The descriptors (Leq or L10) used to quantify these measurements shall be consistent with the descriptors used for the predicted levels and the design noise levels in Figure 3-1. Measurement systems shall, as a minimum, meet the requirements for Type 2 instruments as specified in ANSI Standard S1.4-1971.

      4. Compare the predicted traffic noise levels for each alternative under detailed study with the existing noise levels and with the design noise levels in Figure 3-1. This comparison shall also

include predicted traffic noise levels for the "do nothing" alternative in the design year. Such information shall be used primarily to describe the noise impact of proposed highway improvements in contrast with noise levels likely to be reached in the same area if no highway improvement is undertaken. Noise impacts can be expected when the predicted traffic noise levels (for the design year) approach or exceed the design noise levels in Figure 3-1, or when the predicted traffic noise levels are substantially higher than the existing noise levels. The comparison between predicted traffic noise levels for the proposed action and the "do nothing" alternative (for the design year) may be used in the consideration of exceptions to the design noise levels.

5. Examine and evaluate alternative noise abatement measures for reducing or eliminating the noise impact on existing activities; developed lands; and undeveloped lands for which development is planned, designed and programed. This examination shall include a thorough consideration of traffic management measures (e.g., prohibition of certain vehicle types, time use restrictions for certain vehicle types, modified speed limits, exclusive lane designations, traffic control devices or combinations of such measures). Federal law requires a determination that noise abatement measures needed to implement the noise standards have been incorporated into project plans and specifications before they are approved. Because decisions on noise abatement are prerequisites to determining environmental impacts, and because these impacts influence decisions on adoption of a highway location, it is important that a preliminary determination be made. Before adoption of a highway location, the highway agency shall identify:

   (a) noise abatement measures which are likely to be incorporated in the project, and

   (b) noise impacts for which no apparent solution is available.

6. Identify for Type IA projects those lengths of highway (separately for each side of the highway) and those individual land uses where noise abatement measures appear impracticable or not prudent and which may qualify under the exception procedures (paragraph 9a and b).

c. Upon completion of the noise analysis for Type IA or IB projects, the highway agency shall prepare a noise study report for FHWA concurrence.

   1. The noise study report shall include the following:

      (a) detailed noise analysis and evaluation information (paragraph 7b),

      (b) proposed noise abatement measures including descriptive information which portrays their design details, anticipated

effectiveness in relation to the design noise levels (paragraph 8) and/or existing noise levels and estimated costs and benefits,

(c) requests for exceptions to the design noise levels and supporting information as required and outlined in paragraph 9 (Type IA projects only),

(d) discussion of construction noise analysis information, as required in paragraph 13, including proposed contract provisions to minimize or eliminate adverse construction noise impacts, and

(e) discussion and documentation of coordination with local officials as required in paragraph 10.

2. The noise study report may be in preparation throughout the project development process but shall be concluded prior to approval of the plans and specifications. Preliminary versions of the report shall be prepared as necessary for environmental statements and for input to decisions on selecting a highway location. Depending on the scope and timeliness of a complete noise report, various sections of the report such as noise impact evaluations, proposed noise abatement measures, noise exception requests, etc., may be processed separately and included in the final report.

3. FHWA concurrence in the noise study report shall constitute its approval of all requested exceptions to the design noise levels contained therein and approval of proposed abatement measures contained therein.

d. Highway agencies proposing to use Federal-aid highway funds for Type II projects shall perform a noise analysis similar to that described in paragraph 7b and shall prepare a noise report with recommendations. This noise report shall indicate and describe the noise impacts that have been identified for these type projects. The design noise levels in Figure 3-1 are a suitable yardstick for this determination.

e. In requesting Federal construction funding for a Type II project, the highway agency shall indicate the nature of the proposed Type II project and the relative priority with other potential Type II projects in the State. Some of the suggested factors which may be considered in the development of this relative priority are:

1. applicable State law,

2. type of development to be protected,

3. magnitude of the traffic noise impact,

4. cost - benefits,

5. population density of the affected area,

6. day-night use of the property,

7. feasibility and practicability of noise abatement at the site,

8. availability of funds,

9. existing noise levels,

10. achievable noise reduction,

11. intrusiveness of highway noise (L_{10} - L_{90}),

12. public's attitude,

13. local governments' efforts to control land use adjacent to the highway,

14. date of construction of adjoining development.

15. increase in traffic noise since the development was constructed,

16. local noise ordinances,

17. feasibility of abating the noise with traffic control measures.

8. <u>DESIGN NOISE LEVELS</u>

a. The design noise levels in Figure 3-1 represent a balancing of that which may be desirable and that which may be achievable. Consequently, noise impacts can occur even though the design noise levels are achieved. The design noise levels for Categories A, B, C, and E should be viewed as maximum values, recognizing that in many cases, the achievement of lower noise levels would result in even greater benefits to the community. Every reasonable effort shall be taken to achieve substantial noise reductions when predicted noise levels exceed these design noise levels. However, any significant reduction in the existing or predicted noise level will be a benefit, and partial noise abatement measures shall be included in the project development where they are consistent with overall social, economic, and environmental considerations. On the other hand, the adverse social, economic, and environmental effects of providing abatement measures may be too high. For each case where the circumstances warrant, this directive provides

for FHWA approval of exceptions to the design noise levels for Type IA projects. Exceptions are not required for Type IB and Type II projects.

b. The design noise levels are to be applied to:

1. those undeveloped lands for which development is planned, designed, and programed on the date of public knowledge of the highway project,

2. those activities and land uses in existence on the date of public knowledge of the highway project,

3. areas which have regular human use and in which a lowered noise level would be of benefit. Such areas would not normally include service stations, junkyards, industrial areas, railroad yards, parking lots, storage yards, and the unused open space portions of other developments and facilities. Design noise levels should, however, be applied to those parks and recreational areas or portions thereof where serenity and quiet are considered essential even though such areas may not be subject to frequent human use, and

4. those places within the sphere of human activity (at approximately ear-level height) where activities actually occur. The values do not apply to an entire tract upon which an activity is placed, but only to that portion on which such activity normally occurs.

c. The interior de ign noise levels in Category E apply to:

1. indoor activities for those parcels where no exterior noise sensitive land use or activity is identified, and

2. those situations where the exterior activities on a tract are either remote from the highway or shielded in some manner so that the exterior activities will not be significantly affected by the noise, but the interior activities will.

d. The interior design noise levels in Category E may be considered as a basis for noise insulation of pbulic use institutional structures in special situations when, in the judgment of the highway agency and concurred in by the FHWA, such consideration is in the best public interest.

e. Interior noise level predictions may be computed by subtracting from the predicted exterior levels the noise reduction factors for the building in question. If field measurements of these noise reduction factors are obtained, (or if the factors are calculated from detailed acoustical analyses) the measured (or calculated) values shall be used.

1. In the absence of such calculations or field measurements, the noise reduction factors may be obtained from the following table:

Building Type	Window Condition	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20
	Storm Windows	25
Masonry	Single Glazed n	25
Masonry	Double Glazed	35

2. The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.

3. Situations where open window periods do not coincide with a high traffic noise level may qualify as a closed window condition. In such instances, the optional noise prediction procedure in paragraph 14e shall be used.

DESIGN NOISE LEVEL/ACTIVITY RELATIONSHIPS[1]

Activity Category	Design Noise Levels - (dBA)[2] $L_{eq}(h)$	$L_{10}(h)$	Description of Activity Category
A[3]	57 (Exterior)	60 (Exterior)	Tracts of land in which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose. Such areas could include amphitheaters, particular parks or portions of parks, open spaces, or historic districts which are dedicated or recognized by appropriate local officials for activities requiring special qualities of serenity and quiet.
B[3]	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, and parks which are not included in Category A and residences, motels, hotels, public meeting rooms, schools, churches, libraries, and hospitals.
C	72 (Exterior)	75 (Exterior)	Developed lands, properties or activities not included in Categories A or B above.
D	--	--	For requirements on undeveloped lands see paragraphs 11a and c.
E[4]	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

1. See Paragraph 8 for method of application.
2. Either L_{10} or L_{eq} (but not both) design noise levels may be used on a project.
3. Parks in Categories A and B include all such lands (public or private which are actually used as parks as well as those public lands officially set aside or designated by a governmental agency as parks on the date of public knowledge of the proposed highway project.
4. See Paragraphs 8c, d, and e for method of application.